

13th COTA International Conference of Transportation Professionals (CICTP 2013)

## New Concept of Traffic Rotary Design at Road Intersections

S.K. Mahajan<sup>a</sup>, Anshul Umadekar<sup>b</sup>, Kruti Jethwa<sup>c</sup>

<sup>a</sup>Professor RCET, Khoka, Bhilai, 491001, Chhattisgarh, India

<sup>b</sup>Lecturer; <sup>c</sup>Assistant Professor, RCET, Khoka, Bhilai 491001, Chhattisgarh, India

---

### Abstract

Traffic Rotary at road intersections is special form of grade change of lanes to channelize movement of vehicles in one direction around a central traffic island. With rapid growth of traffic it is experienced that widening of roads and providing flyovers have become imperative to overcome major conflicts at intersections such as collision between through and right-turn movements. In this way, major conflicts are converted into milder conflicts like merging and diverging. The vehicles entering the rotary are gently forced to move in a clockwise direction. They then weave out of the rotary to the desired direction. The crossing of vehicles is avoided by allowing all vehicles to merge into a stream around the rotary and then to diverge out to the desired radiating road. Thus the crossing conflicts eliminate and convert into weaving manoeuvre or a merging operation from right and a diverging operation to the left. In this paper, designing rotaries at road intersections is discussed and a software package is developed to be used in road works.

© 2013 The Authors. Published by Elsevier Ltd. Open access under [CC BY-NC-ND license](http://creativecommons.org/licenses/by-nc-nd/4.0/).

Selection and peer-review under responsibility of Chinese Overseas Transportation Association (COTA).

**Keywords:** Road Intersection; Global Math; Geomatic-Road-Software; Rotary Design;

---

### 1. Introduction

Rotaries are suitable when the traffic entering from three or more approaches are relatively equal. A total volume of about 3000 vehicles per hour can be considered as the upper limiting case and a volume of 500 vehicles per hour is the lower limit. Rotaries are suitable when there are more approaches and no separate lanes are available for right-turn traffic thus making intersection geometry complex. The traffic operations at a rotary are three; diverging, merging and weaving.

- Diverging: when the vehicles moving in one direction is separated into different streams according to their destinations.
- Merging: is referred to as the process of joining the traffic coming from different approaches and going to a common destination into a single stream.
- Weaving: is the combined operation of both merging and diverging movements in the same direction.

## 2. Current Practice of Rotary Design

The design elements include design speed, radius at entry, exit and the central island, weaving length and width, entry and exit widths. In addition the capacity of the rotary can also be determined by using some empirical formula. A typical rotary and the important design elements are shown in figure (1).

## 3. Design Speed

All the vehicles are required to reduce their speed at a rotary. Therefore, the design speed of a rotary will be much lower than the roads leading to it. Although it is possible to design roundabout without much speed reduction, the geometry may lead to very large size incurring huge cost of construction. The normal practice is to keep the design speed as 30 and 40 kmph for urban and rural areas respectively.

### Nomenclature

a	small chord of the circle (least side of a triangle)
b	greater side of triangle out of sides a and b
R	radius of circum-circle passing through point A,B and C of the triangle
$e_1$	width of road at entry point and $e_2$ - width of weaving section of road

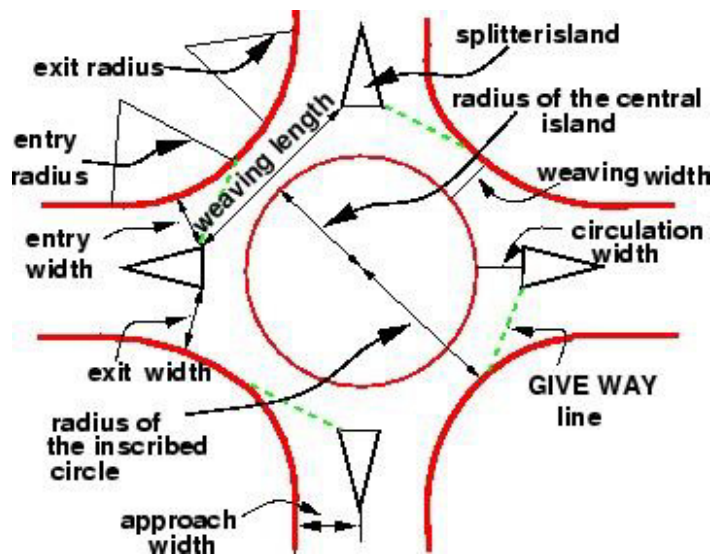


Fig. 1. Design of a Rotary

## 4. Entry, Exit and Island Radius

The radius at the entry depends on various factors like design speed, super-elevation, and coefficient of friction. The entry to the rotary is not straight, but a small curvature is introduced. This will force the driver to reduce the speed. The speed range of about 20 kmph and 25 kmph is ideal for an urban and rural design

respectively. The exit radius should be higher than the entry radius and the radius of the rotary island so that the vehicles will discharge from the rotary at a higher rate. A general practice is to keep the exit radius as 1.5 to 2 times the entry radius. However, if pedestrian movement is higher at the exit approach, then the exit radius could be set as same as that of the entry radius. The radius of the central island is governed by the design speed, and the radius of the entry curve. The radius of the central island is about 1.3 times that of the entry curve for all practical purposes.

### 5. Shape of Central Island:

The shape and disposition of central island (control island) depend upon various factors such the number and disposition of intersecting roads and traffic flow pattern. Fig (2) illustrates the common shapes of rotary islands. The conditions under which a particular shape is favoured are discussed below:

Table 1.

Type	Central Island
Circular	Equal importance to all road meetings
Squares with rounded legs	Suitable for predominantly straight ahead flows
Elliptical, elongated, oval or rectangular.	To favour through traffic/to suit the geometry of the intersecting legs/ to provide longer weaving lengths.
Irregular	Shape is dictated by existence of large number of approaches.

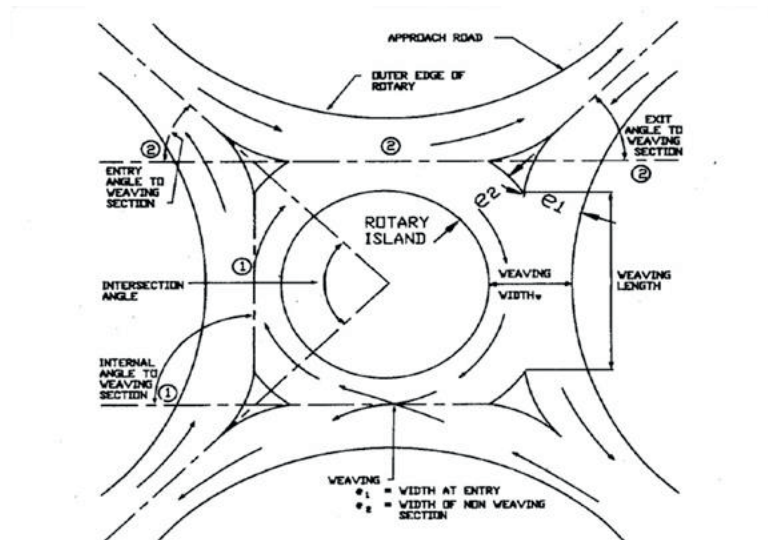


Fig. 2. Design Parameters of a rotary

### 6. Width of the Rotary

The entry width and exit width of the rotary is governed by the traffic entering and leaving the intersection and the width of the approaching road. The width of the carriageway at entry and exit will be lower than the width of the carriageway at the approaches to enable reduction of speed. IRC suggests that a two lane road of 7 m width

should be kept as 7 m for urban roads and 6.5 m for rural roads. Further, a three lane road of 10.5 m is to be reduced to 7 m and 7.5 m respectively for urban and rural roads. Traffic rotaries reduce the complexity of crossing traffic by forcing them into weaving operations. The shape and size of the rotary are determined by the traffic volume and share of turning movements. Capacity assessment of a rotary is done by analyzing the section having the greatest proportion of weaving traffic. The analysis is done by using the formula given by the width of the weaving section and it should be higher than the width at entry and exit. Normally this will be one lane more than the average entry and exit width. Thus weaving width is given as,

$$W = \text{weaving} = \left( \frac{e_1 + e_2}{2} \right) + 3.5m \quad (1)$$

Where  $e_1$  is the width of the carriageway at the entry and  $e_2$  is the carriageway width at exit. Weaving length determines how smoothly the traffic can merge and diverge, Fig. (2). It is decided based on many factors such as weaving width, proportion of weaving traffic to the non-weaving traffic etc. This can be best achieved by making the ratio of weaving length to the weaving width very high. A ratio of 4 is the minimum value suggested by IRC. Very large weaving length is also dangerous, as it may encourage over-speeding.

## 7. Weaving Length:

The weaving length determines the ease with which the vehicle can maneuver through the weaving section and thus determines the capacity of the rotary. The weaving length is decided on the basis of the factors, such as, the width of weaving section, average width of entry, total traffic and proportion of weaving traffic in it. It is desirable to prevent direct traffic cuts and this can be achieved by making the ratio of weaving length to weaving width large enough. A ratio 4:1 is regarded as minimum. The minimum values of weaving lengths as recommended by IRC are given below:

Table 2.

Design speed (kmph)	Minimum length of weaving (m)
40	45
30	30

## 8. New Concept to Design Rotary at Road Intersections -

Concept of ‘Global Math’ was invented by Dr. S.K. Mahajan in 2008, while finding an answer to a problem asked on Internet stated below:

“Determine the radius of a circle in which lengths of two chords ‘a’ and ‘b’ are known and the chords meet at any point on the periphery of the circle?”. The equation derived as solution of the problem is given below. It is a quadratic equation in terms of  $R^2$ .

$$\left\{ 1 - \left( \frac{a}{b} \right)^2 \right\} R^4 - \left\{ \frac{b^2 - 5a^2}{4} \right\} R^2 - \frac{a^2 b^2}{2} = 0 \quad (1)$$

Above innovative geometrical concept is used by the authors in rotary designs.

## 9. Design Consideration

- Length of Intersecting straights with minimum site distances recommended by I.R.C. are: 50 km/h.,
- Minimum Sight distance 15 m along minor roads

- iii. Weaving Distance = 110 m, 145 m, 180 m and 220 m for speeds 50 km/h., 65 km/h., 80 km/h, 100 km/h. respectively. Minimum Weaving length: 30 to 50 m
- iv. All traffic islands are constructed 200 mm higher than road level. They are provided with lawn, statue or fountains, painted with colours in contrast with the road pavement.

#### 10. The Problem Selected for the Rotary Design is Stated Below:

A flyover between the two Rotaries  $R_1$  and  $R_4$  is constructed very recently (marked in red colour) to ease out the traffic jam between the stretch of 330 m long road from  $R_1$  to  $R_2$  rotaries in location plan Fig.(3). The frequent closure of railway gate between  $R_1$  and  $R_2$  often makes the traffic jam overloaded hence the new flyover is constructed. The rotaries  $R_1$  and  $R_4$  are therefore modified using Dr. Mahajan's eq.(1)

The rotary model data is observed as: weaving distance = 110 m and intersection angles opposite to weaving distance observed at the site the curve details are computed from eq. (1), Fig.(4). Let there are 5 roads intersecting at a central point Fig.(4). There will be 5 different sight distance triangles marked with different colours green, red, black, red and blue lines.

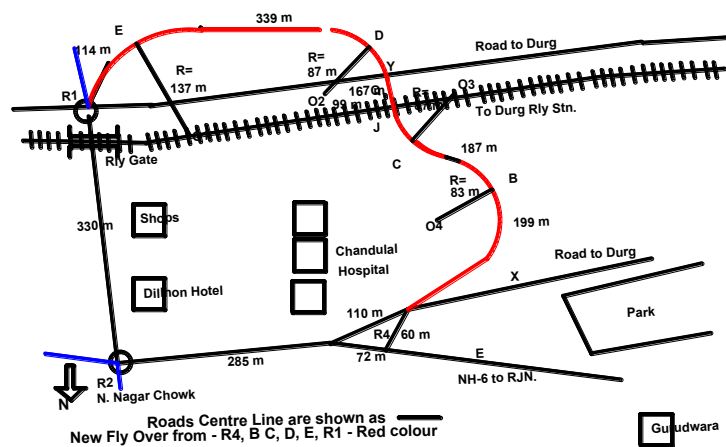


Fig. 3. Location Plan of new flyover between  $R_1$  and  $R_4$

Each sight distance triangle will have minimum sight distance = 110 m and intersection angles observed at the site are  $27^\circ$ ,  $63^\circ$ ,  $84^\circ$ ,  $96^\circ$  and  $90^\circ$  respectively. The radius of circum-circle for sight distance triangle is given by  $R = 110 * 0.5 / \sin \theta$ , where  $\theta$  is angle opposite to sight 110 m of the triangle. The different values of  $R$  are tabulated in table 2 are 121.15, 55.01, 55.30, 55.36 and 60.69 m respectively.

\* The surveying and mapping technology has seen drastic change to development of information and space technology. The earlier used tape and chains have been replaced by laser distance meter of different ranges. The economy in application is enhanced by geomatic software. It can be realized in following stages:

- i) Less Number of field observation and time saving in fieldwork
- ii) Other required quantity can be computed in the office from observed data on computers.
- iii) Data observation with laser distance meter, having capacity to measure 250m is very useful particularly in rotary design projects.

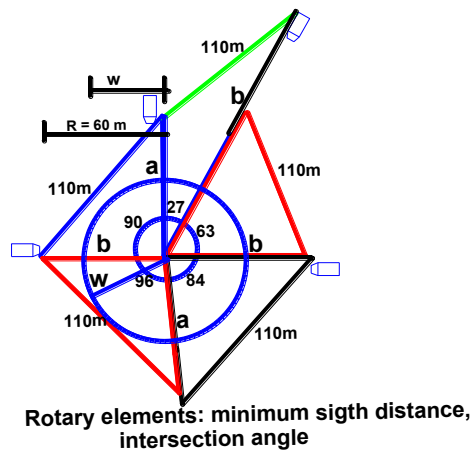
Fig. 4. Location Plan of new flyover between R<sub>1</sub> and R<sub>4</sub>

Fig. 5. Model Data to design a rotary

$$\left\{1 - \left(\frac{a}{c}\right)^2\right\} R^4 - \left\{\frac{c^2 - 5a^2}{4}\right\} R^2 - \frac{a^2 c^2}{2} = 0 \quad (2)$$

Eq.(1) is rewritten with sides a and c, replacing b with c, because side c = 110 m is known. Substituting the value of R = 121.05, c = 110 m in eq.(2) we get a = 84.08 m and b = 194.72 m. Thus each of the sight triangles can be solved knowing two elements i.e. 110 m and its opposite angle, the intersection angle of two roads at the rotary junction. Excel sheet for computation for the sides a, b and R is prepared for rapid solution of all the 5 sight distance triangles. The minimum side 'a' of all the 5 triangles is accepted as the required radius of the rotary R marked in Fig.(5). Computation of required design data of two rotaries R<sub>1</sub> and R<sub>4</sub> are tabulated below from the result of the software developed on the basis of above sample calculation explained above. Excel sheet software to compute rotary elements using laser distance meter for observed is given in Annexure-1

Table 3. Computation of all elements of a triangle R<sub>4</sub> with One Side & given angle opposite to it

Observations	Chord	Opp. Angle	Sides of $\Delta$		
Chord Lengths	b	$\theta$	R	c	a
Rotary R <sub>4</sub>	110	125	67.12	90.02	65.02
	110	50	71.80	98.76	67.03
	110	84	55.30	65.44	62.28
	110	101	56.03	67.66	61.74

Table 4. Computation of all elements of a triangle R<sub>4</sub> with One Side & given angle opposite to it

Observations		Chord	Opp. Angle		Sides of $\Delta$	
Chord Lengths		b	$\theta$	R	c	a
Rotary	at A	110	27	121.15	194.72	84.08
	R <sub>1</sub>	110	91	55.01	63.78	63.26
		110	96	55.30	65.44	62.28
		110	84	55.30	65.44	62.28
		110	65	60.69	77.69	62.45

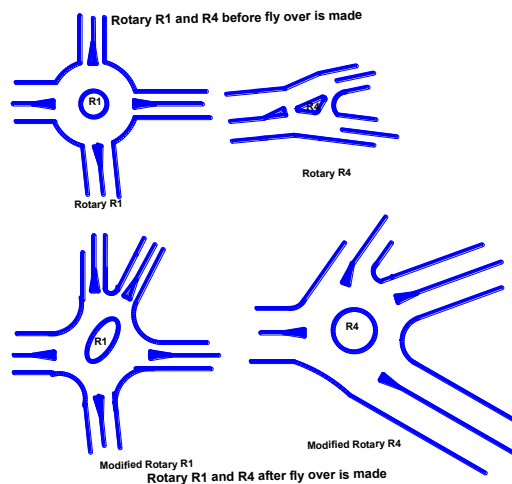


Fig.6. New Concept of Rotary Design with Model Data

The rotaries R<sub>1</sub> and R<sub>4</sub> before and after the construction of flyover are shown in Fig.(6) below. From Table 1 and 2, the minimum radius of rotary are obtained as: at R<sub>1</sub> = 62.45 m and R<sub>4</sub> = 61.74 m Fig.(6). It is the minimum side 'a' out of the sight triangles formed at the two rotaries. The median with island construction on each intersecting road starts from the outer point 60 m of rotary radius R, and ends at the inner circle marked with w, the width of the road at the roundabout. The width w = 35 m, and the radius of the central island = 10 m.

## 11. Conclusion

A new geometric concept is discussed to design rotaries at intersection of roads. The design requires less data observation in the field. It finds wide application in road works planning and design. The geomatic road engineering software is prepared to compute the following with less data observations in the field:

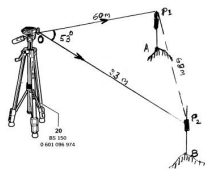
- To determine the quantity of earthwork from mass haul diagram
- To check the stability of the earthen embankment
- To design road curves negotiating three continuous straight roads of a traverse
- To select a suitable road alignment from a location plan and to design rotaries at the ends of a flyover.

## References

- Mahajan, S.K. (1971). Explicit Approach to Exterior Orientation. *Journal of Surveying & Mapping Division*, 97, 251-265.
- Mahajan, S.K. (2008). Invention Intelligence. National Research Development Corporation (A Government of India Enterprise).
- Mahajan, S.K. (2008). Global Mathematics – a new dimension for problem solving. *Indian valuer journal*.
- Mahajan, S.K. (2009). Experimenting in Math. *Teacher Plus Magazine*.
- Mahajan, S.K. (2008). Global Mathematics for Network Analysis. DoMS I.I.T. Roorkee guest lectures.
- Mahajan, S.K. (2009). Global Mathematics – Amendments in Fundamental Mathematics. Presented in 75th Platinum Jubilee Conference of the Indian Mathematical Society, Kalasalingam University, Tamilnadu, India.
- Mahajan, S.K. (2010). New geometrical tools to value extent of open land. *Indian valuer journal*.
- Mahajan, S.K. (2009). Global Mathematics and its interdisciplinary applications. *Emerging Journal on Engineering Science and Technology*.
- Mahajan, S.K. (2012). Geomatic Applications software in Civil Eng. Projects. *International Journal of Advanced Civil Eng.*
- Mahajan, S.K. (2012). Globematic Science, e-Book: [www.Pothi.com](http://www.Pothi.com).

## Appendix A. Global math application software

Formula to give Solution of Triangle by two elements  $\left\{1 - \left(\frac{a}{b}\right)^2\right\}R^4 - \left\{\frac{b^2 - 5a^2}{4}\right\}R^2 - \frac{a^2b^2}{2} = 0$



Two sides of triangle are given

Particulars	Given Data		Result	Type of Triangle	
Elements of Triangle	A	b	R	PI correction	
Ratio b/a	60	68	1.1333	1.511438	0.3027966
a		1		1.208641	
b		1.13333		0.777381	



## Quadratic Equation Computation

Coeff of $R^4$	0.22145	All Acute Angle $\Delta$	
Coeff of $R^2$	4.19451		
Constant	-2.90003	Thus 3 elements of $\Delta$	
Value of $R^2$ from Eq.(1)	0.6043	a	b
		60	68
Sin Angle A = $a/2R$	0.6432	0.78	Angle A 40.03
Angle (degrees) A =	40.03		Angle B 53.14
Sin B = $b/2R$	0.7289		Angle C 86.83
B	46.798	c	93.14
Angle A+B	86.828		
Therefore Angle C =	93.172		
Since in the triangle all angle are acute, being stations of a triangulation net			
		$\Delta$ with sides a,b,c' is obtuse	
Exterior Angle of C is		Angle A	40.03
true value of angle C	86.828	Angle B	46.80
Therefore corrected angle B	53.143	Angle C	93.17
		c'	93.14